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AIR POLLUTION IN HAMILTON, OHIO

Paul A. Kenline

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

1960

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TECHNICAL REPORT

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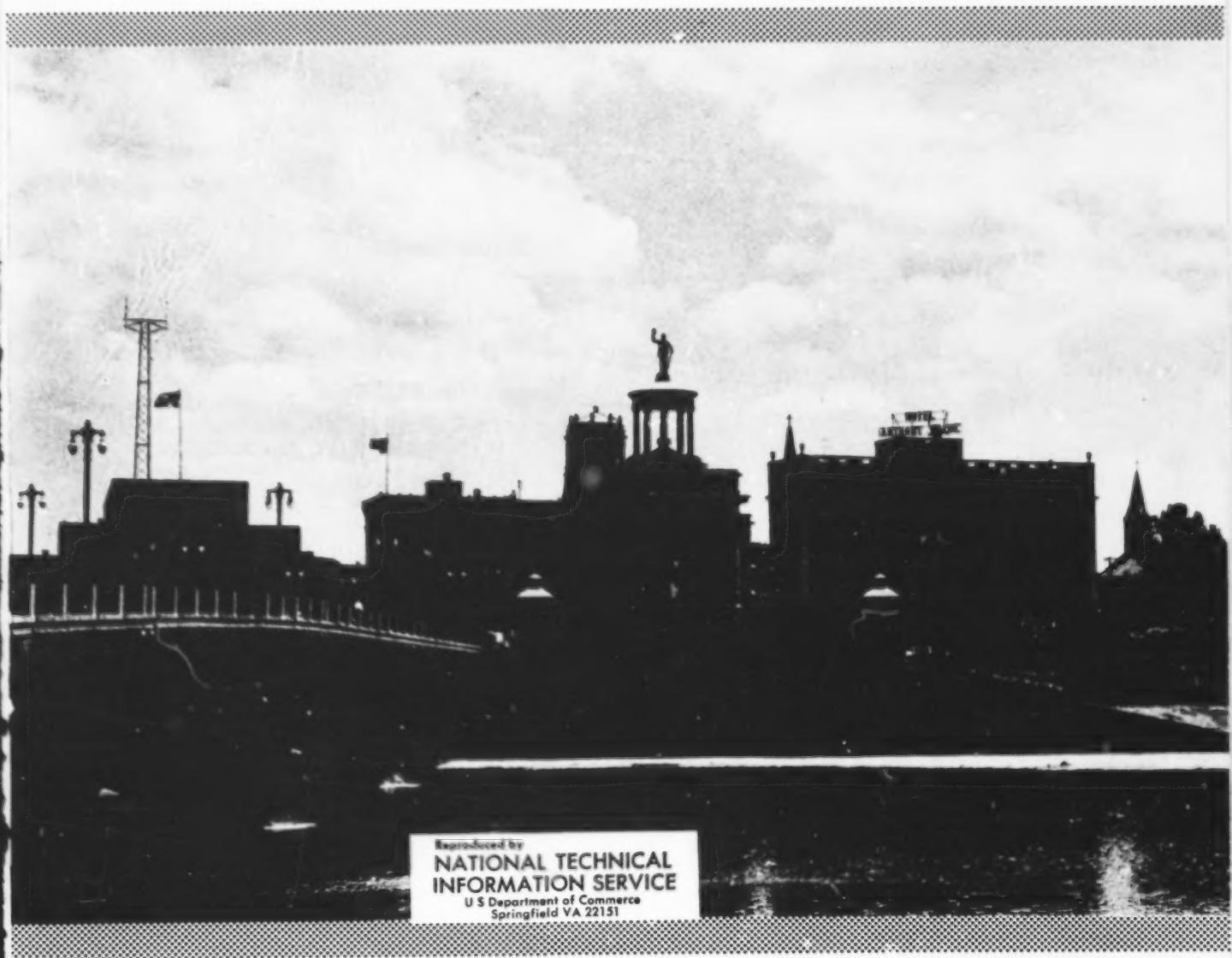
AIR POLLUTION IN HAMILTON, OHIO



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Public Health Service

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AIR POLLUTION IN HAMILTON, OHIO

Paul A. Kenline

Technical Services
Air Pollution Engineering Research

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Bureau of State Services
Division of Engineering Services

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

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I

FOREWORD

Various aspects of air pollution in and near Hamilton, Ohio have stimulated public interest in the development of an effective air pollution control program.

Previous considerations of this subject have been limited in scope and were not intended to result in adequate evaluation of the problems already existent or anticipated, or to develop a comprehensive program to deal with such problems.

This report should provide a constructive basis for a continuing program suitable to the needs of Hamilton. To achieve this aim, this study and its reports will be consummated and presented in three phases:

1. An overall survey of the air pollution problem in the Hamilton area.

2. A sampling program covering an entire year (1960) to show actual conditions found in various locations and at different times of the year.

3. Specific recommendations based on the above for:

   a. Program development including personnel and facilities
   b. Necessary legislation
   c. Correction of existing problems

The first of these phases has been completed and the report is herewith presented. Phase two of the report is under way.

— ALEXANDER WITKOW, M. D., M. P. H.
Director of Health, Hamilton, Ohio

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ACKNOWLEDGEMENTS

The assistance and cooperation of the Hamilton City Health Department, the Ohio Department of Health, and other agencies and organizations which furnished information for this study are gratefully acknowledged.

The cooperation of the following industries to which inspection visits were made also is acknowledged:

American Cyanamid Company

Armco Steel Corporation (Hamilton plant)

Baldwin-Lima-Hamilton Corporation

The Black-Clawson Company

City of Hamilton

- Electric Generating Plant
- Land Fill Operation
- Sewage Treatment Plant

The H. P. Deuscher Company

Hamilton Foundry Incorporated

Herring-Hall-Marvin Safe Company

Leshner Corporation

Mosler Safe Company

National Can Corporation

Pease Woodwork Company, Inc.

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SUMMARY AND RECOMMENDATIONS

SUMMARY

At the request of the Hamilton City Health Department, the Public Health Service made an appraisal in Hamilton of factors relative to air pollution. The Ohio Department of Health and the Hamilton City Health Department assisted in the conduct of the study. The purpose of this appraisal was to determine the status of the air pollution situation and the need for activity on the part of government in solving air pollution problems. This report is an analysis of data and information assembled on air pollution levels, sources, dispersion, and local control activity.

Population gain between 1930 and 1950 amounted to 11 percent. Recent annexations to the city have increased its population by an estimated 30 percent. Continued growth of Hamilton and the surrounding area appears probable, and is a factor favoring higher future pollution levels.

Weather data are not available for the immediate Hamilton area. However, using data from the Cincinnati Weather Bureau and allowing for the effect of local topography, it appears that there frequently are times when atmospheric dispersion is not favorable. While calms are infrequent, light winds occur often, and these may be insufficient to "clear out" pollutants. Winds are predominantly oriented along the Miami River valley in which Hamilton is situated.

Industrial sources of pollutants contribute significantly to Hamilton's air pollution levels. These sources include emissions which are of principal concern to a localized area near the source, and emissions which contribute to the overall community pollution level. Examples of industrial emissions include odors from several sources, dust from a slag and gravel products plant, and emissions from a chemical plant, cupolas, foundries, and various fabricated metal products producers.

Commercial and domestic fuel consumption contributes significantly to the pollution level during the heating season.

Sources of emission, both industrial and nonindustrial, are geographically wide-spread throughout the city. The National Air Sampling Network station located at the municipal building shows no significant difference in measurements of pollution levels associated with different wind directions.

Measurements of total particulate and organic particulate pollutants by the Network indicates that Hamilton has a high level of pollution for its population size, with little tendency for extremely high or low levels. These data indicate that pollution levels are significantly higher during the heating season than the nonheating season, reflecting the contribution of space heating sources. A survey by the Coal Producers Committee for Smoke Abatement (1954) indicated that dense smoke emissions from commercial and industrial boiler plants were numerous. Measurements of sulfur dioxide by Kettering Laboratory, and evidence of vegetation damage, indicate that adverse levels of this gas may be reached for short periods.

Complaints have been concerned with odors from various sources, emissions from a sulfuric acid manufacturer, and soot and smoke from several industrial establishments.

RECOMMENDATIONS

On the basis of this appraisal and on the general available knowledge relating to air pollution, the following recommendations are made:

1. Information should be developed relating in detail to air pollution levels and sources. Consideration should be given to:

   a. A limited air sampling program of both particulate and gaseous pollutants, including dustfall, suspended particulate matter, soiling characteristics, sulfur dioxide, and dense smoke emission.

   b. A short-term meteorological study to establish the reliability of using extensive

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data from the Cincinnati Weather Bureau to characterize the Hamilton area. Wind speed and wind direction data are of importance.

2. A modest air pollution program should be developed within the health department. This program initially might consider the following:

   a. Establishment of laboratory facilities to support field investigations.

   b. Investigation and abatement of justified causes of public complaint.

   c. Control of sources of pollution detrimental to the health, comfort, safety, or welfare of the public.

3. In connection with this program, the health department should consider the desirability of promulgating regulations concerned specifically with air pollution control beyond the existing general nuisance laws.

4. The present ordinance concerning dense smoke emissions should be revised.

AIR POLLUTION IN HAMILTON, OHIO

INTRODUCTION

THE STUDY

This appraisal of air pollution was initiated at the request of Dr. Alexander Witkow, Commissioner of Health, City of Hamilton Health Department. The purpose was to review and evaluate the existing and potential air pollution situation, and to develop recommendations for the guidance of the local health department in meeting the problem of air pollution.

The study was limited to available information relative to air pollution including activities causing pollution, evidence of pollution levels, meteorological and topographical influences on the dispersion of pollutants, and to other relevant community characteristics. Personal visits were made to 12 industrial plants and three municipal properties. The study area was the urbanized Hamilton area.

An engineer from the Air Pollution Engineering Research Staff of the Public Health Service's Sanitary Engineering Center spent November 2-6, 1959 in the Hamilton area. An Engineer from the Division of Industrial Hygiene, Ohio Department of Health also participated. Valuable assistance was given by personnel of the Hamilton Health Department, who assembled certain information prior to the survey and who participated in the survey.

THE AREA

Hamilton, county seat of Butler County, is located in southwestern Ohio, 20 miles north of Cincinnati.

Butler County, set in rolling country, has an area of 471 square miles. The entire county is classified as a metropolitan area by the U.S. Bureau of the Census. With a 1950 population of 147,203, it contains two major cities, Middletown (population 33,695) and Hamilton (population 57,951). Figure 1 shows the political subdivisions of the county. 1/ Both cities are major manufacturing areas. The rural county area is an exceptional agricultural region.

The area of interest to this study is the city of Hamilton and surrounding urbanized area. Hamilton is in the south-central portion of Butler County, in the valley of the Great Miami River, and extends into the hills which constitute the valley sides. It is an industrial city. Located here are two factories which make three-fourths of the world's supply of bank vaults and safes, a large automobile body samping plant, one of the largest plants in the world making heavy machine tools, and one of the largest mills making coated paper. The city has a land area of almost 12 square miles.

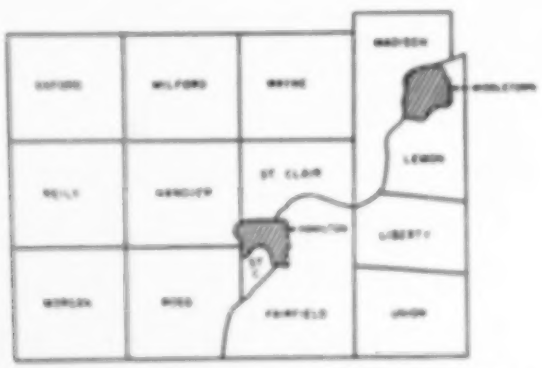

Figure 1. TOWNSHIPS AND CITIES OF BUTLER COUNTY

GENERAL FACTORS AFFECTING AIR POLLUTION

Community air pollution levels depend principally on the type, quantity, and rate of discharge of pollutants to the atmosphere, and on the ability of the atmosphere to disperse these pollutants. The release of pollutants is a function, among other factors, of population, general character of industry and employment, and of land use. The dispersion of pollutants is a function of certain meteorological factors and topography.

POPULATION

The general public is responsible for emission of certain pollutants to the atmosphere. These arise from daily activities, mainly the use of fuels for heat and transportation, and the burning of rubbish. The contribution of an individual is quite small, but taken collectively, the sum of these emissions may amount to a large figure. When people are sparsely settled, as in the more rural areas, these emissions are dispersed into a large volume of air and are readily assimilated into the atmosphere. But as population density increases, more pollutants are released into the given volume of air, and it becomes increasingly difficult for the atmosphere to disperse them. Population figures are used as an index of future pollution levels since the increase in population is accompanied by an increase in pollution emission, both from the activities of the general public itself and from increased industrial-commercial activity.

The 1959 population of Hamilton is estimated at 75,000, an increase of 17,000 over the 1950 census. Hamilton and surrounding area had little increase in population between the 1930 and 1950 census (Table 1). However, recent estimates of population have indicated a substantial increase since. It is anticipated that this area will experience a continued growth.

With a land area of 7.6 square miles, the population density of Hamilton in 1950 was 7625 persons per square mile. Annexations to the city since 1950 have increased its area to about 12 square miles.[3] The current population density is estimated at 6250 persons per square mile. This value is typical of other United States cities of Hamilton's size.

Areas of recent growth near Hamilton are St. Clair (30 percent increase, 1940 to 1950) and Fairfield (50 percent increase, 1940 to 1950) townships. Anticipated future growth is likely to occur in these areas, particularly in Fairfield.

GENERAL CHARACTER OF INDUSTRY AND EMPLOYMENT

Table 2 shows the total employment in Butler County and in Hamilton, and compares Hamilton to the United States. It is apparent that Hamilton has a high ratio of manufacturing employees. Emissions from industrial manufacturing plants may thus be anticipated to be of significance. In 1954, 98 manufacturing establishments were listed in Hamilton.[4] These industries employed 14,025 persons and had an annual payroll of $61,365,000. Value added by manufacturing amounted to $107,818,000.

Leading manufactures include paper products, automotive parts, diesel engines, machine tools, general machinery, aviation parts, safes and vaults, coke, pig iron, stoves, prefabricated homes, foundry products, cans, and millwork.

TABLE 1. POPULATION GROWTH[1,2]

Year	Butler County	Percent urban	Hamilton	Hamilton area*	Balance of county
1959	...	...	75,000	...	...
1950	147,203	70.6	57,951	73,020	74,183
1940	120,249	70.3	50,592	61,353	58,896
1930	114,064	...	52,176	60,950	53,134

*City of Hamilton, Fairfield township, Hanover township, St. Clair township

LAND USE

An analysis of land use in Hamilton shows intermixing of industrial, residential and commercial uses. Such a pattern promotes occurrence of pollution problems, since major pollution sources and susceptible receptors are brought into close proximity.

Hamilton has a zoning ordinance. The zoning boundaries generally correspond to current land use. The ordinance controls the encroachment of industry into residential areas, but not conversely. Certain industries are excluded altogether, e.g., fertilizer manufacture, except by approval of the city council.

TABLE 2. EMPLOYMENT BY GENERAL CATEGORY, 1950[1/]

Industry	Number employed		Percent employed, excluding agriculture and mining	
	Butler County	Hamilton urban	Hamilton urban	United States
Agriculture, Forestry and Fisheries	2,454	97	...	...
Mining	38	17	...	...
Construction	3,227	1,357	5.6	5.2
Manufacturing	26,356	12,236	50.6	34.1
Primary metals	6,229	936	3.9	
Fabricated metals	2,688	1,994	8.2	
Machinery	3,833	2,488	10.3	
Motor Vehicles	2,980	2,115	8.7	
Chemical	186	56	0.2	
Other	10,440	4,647	19.3	
Transportation, Communication and Public Utilities	2,473	1,180	4.9	8.3
Trade	8,542	4,138	17.1	22.0
Finance, Insurance and Real Estate	1,512	903	3.7	4.5
Services and Miscellaneous	9,479	3,717	15.3	25.9
Government	1,313	672	2.8	
Total	55,394	24,317	100.0	100.0

DISPERSION OF POLLUTANTS

TOPOGRAPHY

The topography of the general area consists of gently rolling hills. Hamilton is situated on the Great Miami River, mainly in the valley of this river, but also extending into the nearby hills. The valley is roughly two miles wide, and is oriented southwest - northeast. The neighboring hills rise 100 to 300 feet above the valley floor.[5/] This valley affects the wind

pattern for the area to the extent that channeling occurs in the valley. Generally wind flow is oriented along the valley. It does not appear that the valley is developed to the extent that valley winds caused by cold air drainage, uneven slope heating and the like will occur.

CLIMATOLOGICAL FACTORS IN AIR POLLUTION

Weather factors which determine the degree to which the atmosphere can disperse pollutants are: a) wind speed, direction, turbulence and variability; b) stability or more generally the resistance to vertical motion of the lower layers of air; and, c) humidity and condensation forms, particularly fog.

Transportation and dispersion of pollutants are essentially proportional to wind speed. Generally, the greater the wind speed, the greater the dispersion of air-borne waste materials.

Stability is an important factor in the relationship of meteorology to air pollution. A temperature inversion, indicative of extreme stability, tends to restrict vertical mixing. When this occurs, the capacity of the atmosphere to disperse pollutants is greatly reduced. Shallow inversions based at or near the earth's surface may be produced nightly under clear skies and with light winds. They may inhibit vertical diffusion as long as they persist. This type of inversion usually breaks up in the late morning.

The role of humidity, including condensation in the form of drizzle, snow and rain, is not as direct as that of wind and stability. Condensation forms may have a direct effect by "rain out" (removal of pollutants during precipitation). The presence of fog usually limits solar heating, which affects the degree of vertical diffusion in the lower layers of air.

Investigations of known air pollution episodes have identified all three of these weather elements as contributing to the accumulation of abnormally high concentrations of air pollution. The simultaneous occurence of light winds, stable conditions, and fog for brief periods is not particularly a rare phenomenon, especially in hilly country. Experience suggests that such conditions must persist for several days before abnormally high concentrations of pollutants occur. These persistent periods are usually associated with the prolonged stagnation of high pressure systems.

STAGNATING AIR MASSES

Major air pollution episodes are usually related to the incidence of stagnating anticyclones over or near urban areas for a protracted period (four days or more). During such periods, surface wind speeds may become insufficient to carry away the accumulation of pollutants in the local atmosphere. A study was made of the location and frequency of stagnating anticyclones in the eastern United States, for the period 1936-1956.[6] In southwestern Ohio, 26 cases of stagnation lasting four or more days (a total of 130 days) occurred in the 21 year period, including two cases when stagnation lasted for seven or more days. Nearly 60 percent of the total cases occurred in the three month period August through October. Not all of these cases necessarily result in air pollution episodes; the presence of calms or light shifting winds, and appropriate stability are also necessary.

GENERAL CLIMATOLOGY

Weather data are not collected at Hamilton. For the purpose of evaluating the atmosphere's dispersion potential, data from the Cincinnati Weather Bureau station are used.[7] These weather data characterize general climatology of Hamilton, but due to the distance between Hamilton and the weather station the applicability of specific figures is reduced.

The average monthly wind speed is 9.7 mph, varying from a low of 6.8 mph in August to a high of 12.1 mph in January. A marked seasonal variation in average wind speed occurs. Winds are weaker and calms are more frequent during the warm months than during the cold months (Table 3). Ventilation, and hence atmospheric dispersion potential, is better from November through April than during the remainder of the year.

The prevailing wind direction is south to southwest (Figure 2)[7]. These directions prevail for every month. There is however, a seasonal variation in wind direction (Figure 2). North through east winds are more frequent in the summer (May to October) than during the rest of the year. This difference in wind direction apparently does not affect the community

TABLE 3. SEASONAL VARIATION OF WIND CHARACTERISTICS[7]

	November-April	May-October	Annual
Percent calms	2	5	3.4
Average monthly wind speed	11.5	7.9	9.7
Percent of observations with wind speeds 7 mph or less	25	52	38
Percent of observations winds from North*	31	33	32
Percent of observations winds from Southwest**	57	45	51

*Northwest through Northeast
**South through West

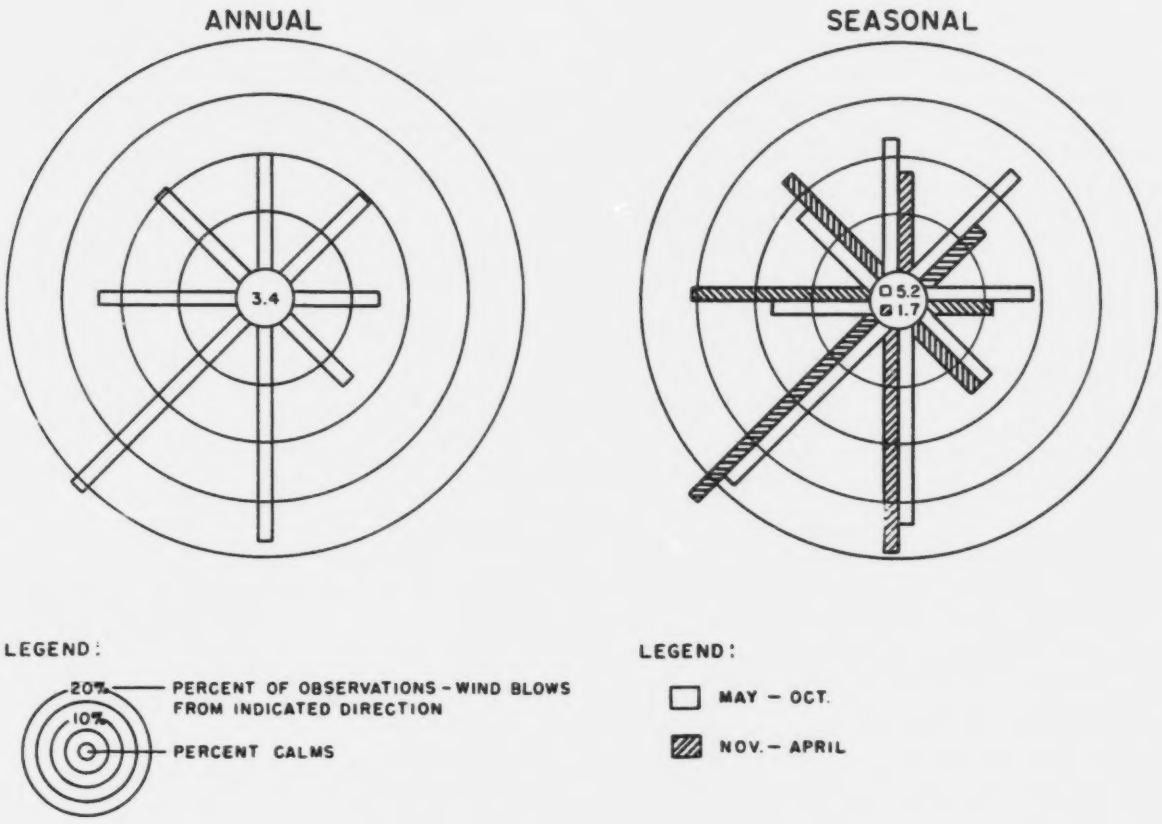

Figure 2. WIND ROSES

pollution level (cf. section "National Air Sampling Network" later in report) in downtown Hamilton. It will affect localized pollution conditions, however.

Nighttime inversions, caused by the radiative cooling of the earth's surface, are probably frequent in this area, as at any inland station. Such inversions are shallow, generally reaching only a few hundred feet. They restrict the vertical movement of air and, hence, the dispersal of pollutants. These inversions are usually dissipated by mid-morning. Momentary high levels of pollutants may result from the "fumigation effect" as the inversion breaks up. These inversions, associated with weak nighttime winds can abet nuisance conditions of short duration.

From this evaluation it appears that the potential for atmospheric dispersion of pollutants is fair.

SOURCES OF POLLUTANTS

POLLUTION FROM FUEL USAGE

The combustion of fuel for space and water heating, for power generation, and in industry releases pollutants to the atmosphere. The amount and type of pollutants are affected by type of fuel, type and condition of firing equipment, load demands, firing practice, and use of collection devices. Excluding that of industries and the steam-electric plant, fuel usage in Hamilton may be approximately summarized as: gas, 58 percent; oil, 20 percent; and coal, 22 percent (on a BTU potential basis). [8]

Coal: Considerable coal is burned in Hamilton. Domestic consumption is estimated at 32,000 tons per year and commercial consumption at 20,000 tons per year. The municipal steam-electric plant uses 100,000 tons per year. Industrial consumption is also large. While complete data on industrial usage could not be collected, for several industries the following consumptions were obtained: a ferrous foundry with three cupolas, 5000 tons per year; a large producer of machinery, 4000 tons per year; and a moderate sized paper industry, 5000 tons per year. Pollutants from the combustion of coal consist of smoke and solids, sulfur dioxide, and other materials (Table 4).

Oil: The annual consumption of fuel oil for residential and commercial heating is estimated at 8,040,000 gallons. The combustion of fuel oil releases aldehydes, nitrogen oxides, sulfur oxides, organic acids, other organic material and ash to the atmosphere (Table 4). From properly maintained and operated oil burners there should be no visible smoke. It is therefore essential to the smokeless operation of oil burning heaters that they be properly adjusted, maintained and operated.

Gas: Natural gas usage (June 1958 - May 1959) amounted to 3,365,103 MCF (thousands of cubic feet), divided by general usage as:

Residential	2,457,994 MCF
Commercial	679,208 MCF
Industrial	227,901 MCF

The combustion of gas does not produce visible smoke but does produce pollutants which add to the overall atmospheric burden of aldehydes, nitrogen oxides, organic acids, and other organic materials (Table 4). Gas consumption remains fairly constant over the year.

TABLE 4. EXAMPLES OF EMISSIONS FROM COMBUSTION OF FUEL OIL, [9] GAS, [9] AND COAL [10]

Component	Pounds of pollutants per ton of material burned		
	Gas (a)	Oil (b)	Coal (c)
Aldehydes	2.0	2.6	...
Nitrogen Oxides	13.8	27.0	8
Sulfur Oxides	...	60.0	40
Acids	2.6	27.0	30
Organics	2.8	9.2	20
Solids	...	2.0 [10]	200

(a) one ton of natural gas is equivalent to approximately 43,570 cubic feet (46 million BTU)

(b) one ton of No. 2 fuel oil is equivalent to approximately 280 gallons (39 million BTU)

(c) one ton of coal contains approximately 24 million BTU

Generation of Electricity: The municipal steam-electric plant burns approximately 100,000 tons of high volatile coal per year in six boilers. All boilers are underfeed-stoker fired. The two largest boilers have low draft dust collectors and discharge to 125 foot stacks. The other boilers have no pollution controls and discharge to a 264 foot common stack. While plant operation is good, it is estimated that this plant will emit smoke and flyash.

Residential Use of Fuel: Coal was the predominant fuel used for residential heating in 1950 (Table 5). In recent years coal usage has dropped markedly, with a corresponding increase in gas and oil usage, particularly gas. While accurate figures are not available, on the basis of fuel consumption it may be estimated that the current ratio of coal: oil: gas heated homes is approximately 1: 1: 3. The combustion of coal in private residences takes place under far from ideal conditions.

Seasonal Variation in Fuel Consumed for Space Heating: Use of fuel for space heating is not evenly distributed over the year, but corresponds to occurrences of colder weather. The use of fuel for heating can be related to heating degree days (Table 6). The five month period November through March constitutes 82 percent of the space heating contribution to air pollution. Fuel consumption in Hamilton is expected to contribute significantly to the air pollution problem, particularly during the heating season.

POLLUTION FROM TRANSPORTATION

Motor Vehicles: The role of motor vehicle exhausts in air pollution is of increasing concern in large communities throughout the country. These vehicles emit significant quantities of hydrocarbons and nitrogen oxides, and smaller amounts of aerosols, oxides of sulfur, aldehydes, ammonia, organic acids, and other organic compounds. Other pollutants result from the use of additives in gasoline such as tetraethyl lead, and boron and phosphorous compounds, and from motor oils and their additives (Table 7).

TABLE 5. FUEL USAGE FOR RESIDENTIAL HEATING - 1950[11] AND 1959

Fuel	Number units so heated (1950)	Percent (1950)	Estimated percent (1959)
Coal	11,910	69.0	20
Wood	55	0.3	...
Gas	3,110	18.0	60
Liquid	1,690	9.8	20
Electricity	15	0.1	...
Other	370	2.2	...
Unknown	100	0.6	...

TABLE 6. HEATING DEGREE DAYS[12]

Month	Degree days	Percent of heating load
Jan	1020	20.4
Feb	869	17.4
Mar	690	13.8
Apr	380	7.6
May	145	2.9
June	16	0.3
July	1	0.0
Aug	4	0.1
Sept	65	1.3
Oct	275	5.5
Nov	609	12.2
Dec	927	18.5

In 1959, 80,000 motor vehicles, including 67,000 automobiles, were registered in Butler County. Hamilton's share of these automobiles amounted to 35,000. Traffic counts (1959) indicate that 115,000 vehicles enter and leave the city daily by major arteries. Within the city some 56,400 vehicles cross the three bridges over the Miami River (east-west flow), while north-south flow on major streets well within the city amount to 30,000 vehicles daily. While no data on gasoline consumption are directly available, it may be estimated on the basis of dollar sales, that 28,500,000 gallons are sold annually in Hamilton.[4] An additional 33,000,000 gallons is sold annually in the rest of Butler County. While these automobiles do contribute to the overall pollution of the atmosphere, it seems unlikely that this number of vehicles will create a severe condition such as exists in Los Angeles. Odors and sometimes smoke from the combustion of diesel fuel in trucks and buses create a nuisance.

Other Transportation: Hamilton is served by two railroads, which are exclusively diesel powered. There is no need for the existence of a smoky diesel locomotive; proper maintenance, adjustment, and operation will prevent such smoke. While combustion of diesel fuel releases pollutants to the atmosphere, its contri-

TABLE 7. EMISSIONS FROM MOTOR VEHICLES

Component	Pounds of pollutants per 1000 pounds of fuel consumed	
	Automobiles[13]	Diesel Engines[14]
Acids	0.3	5
Aldehydes	2.8	2.5
Ammonia	0.3	...
Nitrogen Oxide	12.3	24.5
Organics	70.7	...
Particulates	0.05	17
Sulfur Oxides	2.8	5

bution in Hamilton is probably minor. Hamilton is served by a Class II commercial airport. Emissions from this source are insignificant.

WASTE DISPOSAL OPERATIONS

Refuse Disposal: The method of disposal for garbage and rubbish is an important factor in controlling air pollution. Hamilton operates a sanitary land-fill for refuse disposal. This fill appeared to be well operated. Some larger items of refuse such as tree limbs and stumps are burned in the open at the fill. Good land-fill operation eliminates air pollution from refuse disposal.

Sewage Disposal: Hamilton's sewage is treated at a modern (completed in early 1959) sewage treatment plant. This plant is designed for an average flow of 12 million gallons per day. The operation of the plant is reported by the health department to be good, and apparently it does not constitute an objectionable odor source. Some odor is normally associated with a sewage treatment plant. Odors present in the area of the plant at the time of this survey were of low intensity. A 48-inch industrial interceptor sewer discharging into the Miami River near the plant, may be partly responsible for the odors observed.

INDUSTRIAL PROCESS EMISSIONS

Emissions to the atmosphere from industrial processes play an important part in Hamilton's air pollution situation. A brief description of atmospheric emissions from these industries follows. The information presented is taken from the literature, from experience, and from plant visits made during the study. The discussion is general, as no sampling work was undertaken during the survey. In addition to the process emissions, some industries in Hamilton emit dense smoke from the consumption of coal in boilers for the generation of process steam and for space heating.

Food and Kindred Products: Many food processing industries release odorous materials to the atmosphere. These odors are often quite unpleasant and lead to nuisance complaints. Even pleasant odors become nuisances when they persist. The food industry is not as extensive in Hamilton as in the nation on the whole. The health department has received complaints on odors emanating from this industry, and odors from food processing operations were present at the time of this survey.

Lumber and Wood Products: About a dozen plants are involved in producing wood products. Most of these are small millwork plants; one is a large manufacturer of prefabricated homes. These industries have often been reported (in other areas) to create air pollution problems by burning wood wastes and discharging sawdust. No problems of this nature were observed or reported in Hamilton, however. The plant producing prefabricated homes has good dust collection systems.

Pulp, Paper and Products: There are three fairly large plants manufacturing paper, stationery, cards, and similar products. Process emissions from these plants were not evaluated. The plant producing paper and paper board was observed to emit considerable flyash and dense smoke from raising process steam. Odors, which may be of importance from these industries, were not observed during the survey.

Chemical and Allied Industries: The chemical industry is not extensive in Hamilton. One plant produces sulfuric acid (by the contact process), oleum, and aluminum sulfate. Emissions from the manufacture of sulfuric acid (including oleum) consist of sulfur dioxide, and sulfur trioxide and sulfuric acid mist. Emission data reported in the literature have indicated sulfur dioxide concentrations ranging from 0.4 percent to 1 percent (150 - 400 mg per cu. ft.), and sulfuric acid emissions of 2-6 grains per cubic foot. In this industry generally no air pollution

controls are used on the sulfur dioxide emissions, although some plants have utilized ammonium sulfite or sodium sulfite scrubbing systems to effect 70-95 percent removal. Effective removal of sulfuric acid mist has been accomplished with electrostatic precipitators and coke beds (99.9 percent efficiency). "Demisters" which may remove 95 percent of acid emissions from the manufacture of 93-98 percent acid, 15/ are not effective against acid emissions from oleum manufacture (perhaps 25-40 percent efficiency). This plant, which is equipped with demisters, has been the cause of complaints in Hamilton.

Products of Petroleum and Coal: One plant in the Hamilton area produces coke and by-products. This plant operates a battery of 160 ovens and uses 2400 tons of coal per day. Air pollution sources at typical coke ovens include coal handling and preparation, loading of coal into ovens, leakage of gas from oven during coking, discharging coke from oven, coke quenching and subsequent handling, combustion of coke oven gas for heating ovens, manufacturing of coke oven chemicals, and tail gas from by-product processing plant. Many of the ovens at this plant are old, and in poor operating condition, such that oven leakage is pronounced. This plant appears to be a substantial source of pollutants, mainly smoke, particulates from charging and discharging ovens, sulfur gases (H_2S and SO_2), and other gases. These pollutants originate from the coke ovens. Pollution from the coke chemicals (by product) plant does not appear to be a major source. The by-product gas is treated for sulfur removal before the gas is burned in the ovens.

Stone, Clay and Glass Industries: A half-dozen small plants manufacturing structural clay products and concrete products are located in Hamilton. Emissions include a variety of dusts (coarse particulate matter) which may constitute a localized nuisance problem. One plant north of the city, producing sand, gravel, and slag products is a substantial source of particulate emissions.

Primary Metals: Primary metals is an extensive industry in Hamilton. One plant operates two blast furnaces. There are five non-ferrous foundries (aluminum, bronze, brass, and zinc castings), four iron foundries, and one non-ferrous forging plant. The iron foundries operate a total of seven cupolas which produce a total of 68 tons per hour. Although means are available for reducing cupola emissions, only one of these cupolas has any controls to reduce atmospheric emissions. This four ton per hour unit produces nodular iron, and stack emissions are passed through a water-wall washer. This does not appear to be an effective control device. Emissions from cupolas consist mainly of silica, iron oxide, and carbon monoxide. Particulate loadings run about 0.5 grain per cubic foot, sometimes as high as 1-2 grains per cubic foot. Emissions vary greatly, depending on cupola operating conditions. From 5 to 20 pounds of dust are emitted per ton of iron poured. This figure may range as high as 30 pounds per ton. The melting and pouring of non-ferrous metals also give rise to air pollutants. In the blast furnace, gases pass to dust catchers, static washers and precipitators and are then used for heating. These furnaces, thus, are not a large source of pollutants. The sintering plant associated with the blast furnaces, releases some sulfur gases and dust to the atmosphere.

Fabricated Metals: The fabricated metals industry is quite extensive in Hamilton. It includes producers of tin cans, fabricated structural steel, vitreous-enameled products (stoves), automobile stampings, electroplating, wirework, safes and vaults, and other products. It is difficult to evaluate the contribution of such plants to air pollution. In the application of vitreous enamel on metal objects, emissions typically include: dust from preparing the slip (enamel), alkali, acid, and organic solvents from metal preparation baths, dust from sand blasting, smoke and odors from metal burn-off, dust from spraying operations, and gases from the firing operation. In the automobile assembly industry, data collected in Los Angeles County indicate an average use of 32 pounds of organic solvent per automobile; about 25 pounds of organic solvent per automobile were used where enamel was the coating material, and 40 pounds were used where lacquer was the coating material. This solvent is emitted to the atmosphere. In the manufacture of safes and vaults, atmospheric emissions arise from carburizing operations, plaster handling, paint spraying, and extensive grinding and welding operations.

Other Industry: Emissions from other industries include: hydrocarbons from retail filling stations, smoke and odor from scrap handling operations including barrel recovery, smoke and odor from laundries, odors from restaurants and markets, and odors from dry cleaning establishments. These sources are general to

many areas, and no attempt was made to evaluate them specifically for Hamilton.

GEOGRAPHIC DISTRIBUTION OF INDUSTRIAL SOURCES

The city is served by two railroads, whose main lines enter the city from the southeast and run directly through the city to the north, leaving to the northwest and to the northeast. Most of the industries are located along these lines. Industry thus generally stretches through the middle of the city, from southeast to north. Industrial emissions are widely dispersed throughout Hamilton.

INDICATIONS OF PRESENT POLLUTANT LEVELS

NATIONAL AIR SAMPLING NETWORK

Hamilton has been participating in the National Air Sampling Network of the Public Health Service since the first of 1959. Samples of suspended particulate matter are collected by local health department personnel using a high-volume sampler. Samples are collected for a 24-hour period every two weeks. These are analyzed for total particulate matter and organic particulate matter at the Public Health Service's Sanitary Engineering Center in Cincinnati. The data collected for 1959 indicate an average particulate loading (geometric mean*) of 132 micrograms per cubic meter of air with a standard geometric deviation** of 1.438. This average loading is higher than the average loading of all cities on the network, and is higher than the average of all network cities of Hamilton's population class. The low value for the standard geometric deviation indicates that Hamilton will seldom experience very high or very low pollution levels. The maximum particulate loading was 265 micrograms per cubic meter, and the minimum was 67 micrograms per cubic meter.

The content of organic particulate matter in the air averaged 14.7 micrograms per cubic meter, varying from a minimum value of 5.3 to a maximum of 37.9. This amount of organic matter is somewhat higher than the average of all other cities in the network. The ratio of organic matter to total particulate was 0.10, a relatively high value.

The average reflectance value of the particulate samples was 15 percent. Reflectance is used as a measure of the soiling property of the sample. The lower the reflectance reading, the grimier or dirtier is the particulate matter in the air. This value of 15 percent indicates a high soiling level.

If the year is divided into two seasons according to the space heating needs as determined by the number of degree days, a significant difference (as evaluated by Student's t test) is noted in the atmospheric pollutants as measured at the network station (Table 8). This is true of both total particulate and organic particulate levels. The reason for this difference may be ascribed to the use of fuel for space heating.

From these data it would appear that Hamilton has a high average air pollution level, not likely to become extremely high or low, with a significant difference between heating and non-heating seasons.

The network data were analyzed for dependency upon wind direction. No significant differences in particulate loading were found for different wind directions.

PREVIOUS SURVEY ON SMOKE

In 1954 the Coal Producers Committee for Smoke Abatement[16] made an inspection of 21

*The geometric mean, $\bar{x}_g = \sqrt[n]{x_1 \, x_2 \, \ldots \, x_n}$ is used as a more typical average than the arithmetic mean, since it is less affected by extreme values.

**The standard geometric deviation is a measure of the dispersion of the data.

TABLE 8. SEASONAL VARIATION OF MEASURED POLLUTANTS

Season	Months	Percent of degree days	Total particulate (1)	Organic matter (1)	Percent reflectance
Heating	Nov-Mar	82	152	19.7	7
Non-Heating	May-Sept	4.5	137	10.4	23

(1) Micrograms per cubic meter

selected commercial and industrial boiler plants together with 16 school buildings. The 21 plants included 50 boilers plus cupolas and other apparatus using fuel. In the report of this study it was stated: "Approximately 38 percent of the plants were observed emitting smoke of #2 (Ringelmann) density or greater (smoke above this density usually considered objectionable and probhibited) while it was estimated that 71 percent of the plants observed would violate in the due course of time . . ."

COMPLAINTS

An analysis of complaint records can be useful in evaluating the air pollution problem of an area. In Hamilton, public complaints have been directed against a number of odor nuisances, soot and smoke from several industrial establishments, and a chemical plant which produces sulfuric acid. No analysis of complaints was made in this study, since the local health department is aware of the problems. Damage to vegetation has been alleged in the area near the acid plant.

PREVIOUS STUDY ON SULFUR DIOXIDE

Kettering Laboratory located in Cincinnati, conducted an air sampling program in Hamilton 17/, during the period March 24 through May 10, 1958. Four sampling units which automatically took eight three-hour samples per day for sulfur dioxide were operated near a sulfuric acid plant. The acid plant was shut down for two weeks during this period. Three hour samples of sulfur dioxide exceeded 0.1 ppm (parts per million) 14 times during this study. The maximum value was 0.76 ppm. This is a high value for a three-hour average. The odor threshold for sulfur dioxide is 3 ppm, the taste threshold is 0.3 ppm, and vegetation damage has been noted at 0.3 - 0.4 ppm for sensitive plants.

STATUS OF LOCAL ACTIVITY IN AIR POLLUTION CONTROL

There is a local ordinance regulating dense smoke emission. This ordinance is inadequate, and is not enforced.

The health department, operating under general nuisance provisions of the health code, seeks the correction or elimination of nuisance conditions.

CONCLUSIONS

From the results of this study, and on the basis of general knowledge of the air pollution field, the following conclusions are drawn:

1. Census figures show a 20 percent increase in population for the Hamilton area (Table 1) between 1930 and 1950. Estimates since 1950 have indicated a more substantial growth. Continued moderate growth is expected; air pollution levels may be expected to increase with this growth unless steps to control air pollution are taken.

2. Hamilton is a manufacturing center. With a total employment of 24,317 in 1950, 12,236 were engaged in manufacturing. Machinery, motor vehicles, and fabricated metal production accounted for over 50 percent of these employees.

3. Hamilton, though possessing a zoning ordinance, has an intermingling of residential, commercial, and industrial land uses; this situation tends to aggravate pollution problems.

4. The city is situated mainly in the valley of the Miami River. The 100 to 300 foot hills which rise on either side, tend to orient the winds along the valley. A valley-slope circulation probably does not develop.

5. South to southwest winds prevail for the entire year, although some seasonal variation is experienced. Light winds (0 - 7 mph) occur 40 percent of the time. The potential for atmospheric dispersion of pollutants appears fair.

6. The use of fuel for space heating, steam raising, and power generation constitutes a major source of pollutants.

7. Industrial sources constitute another major source of pollutants. These include odors from food processing and industrial operations, and emissions from sulfuric acid manufacturing, coke ovens, sand and gravel operations, and cupolas. Other industrial sources may also be of import.

8. Measurements of air pollution by the National Air Sampling Network for 1959 show a high average particulate loading (132 micrograms per cubic meter), for a city of its size. Pollution levels show a significant seasonal variation.

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